Wilcom

A subsidiary of NAI Technologies, Inc.

CCS105 Exploring Coil

Operating Instructions

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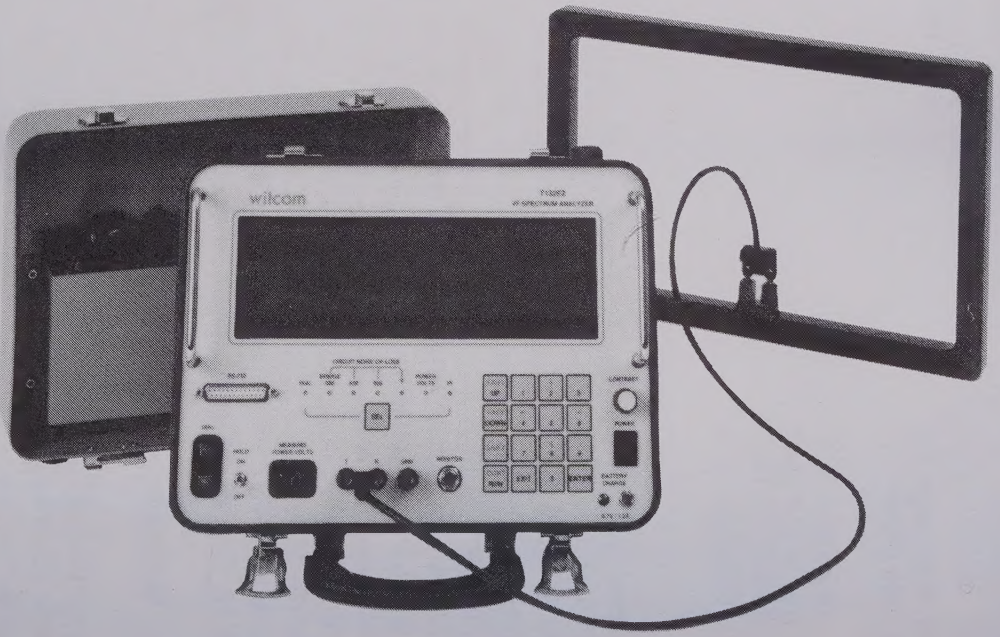


The CCS105 Exploring Coil Shown Connected to the T132EZ Front Panel

Introduction

The Model CCS105 Exploring Coil is designed for use with the T132EZ VF Spectrum Analyzer and the T132B Spectrum Analyzer and Noise Measuring Set. The CCS105 provides a means for measuring ground return currents in power systems without the use of ground rods and a probe wire. This method is much more convenient than the probe wire method, and also provides more accurate measurements, since the effect of any difference in earth surface potential is eliminated.

The CCS105 is a rectangular coil, consisting of a large number of turns of wire in a rigid molded plastic housing, and is equipped with a dual banana jack for ease of connection to the T132EZ or T132B front panel. The coil is large enough for good measurement sensitivity, yet small enough for easy handling and storage. If using the CCS105 with the T132B, the coil can be stored in a compartment in the T132B cover.

Specifications

Operating Frequency Range:	20 to 3500 Hz
Frequency Response (z_{load} $>50K\Omega$):	Frequency Proportional ±1 dB from 20 Hz to 2 kHz, Frequency Proportional ±3 dB from 2 to 3.5 kHz.
Number of Turns:	850
Effective Area:	0.79 ft^2 (.0735 m^2)
Self Inductance:	500 mH (approx.)
Resistance:	300 ohms (approx.)

(Includes 15 kΩ internal shunt provided to smooth response peaks which would otherwise be caused by stray capacitance).

Overall Dimensions:

Height:	14-1/8 in.	(3.6 cm)
Width:	9-7/16 in.	(2.4 cm)
Depth:	13/16 in.	(2.0 cm)
Weight:	2.2 lb.	(1kg)

Using the CCS105

The following is a general procedure for using the CCS105 Exploring Coil with the T132EZ or T132B Spectrum Analyzer. (Refer to the T132EZ or T132B Operating Instructions for additional information about the use of the spectrum analyzer.)

1. Connect a jumper cord with dual banana plugs at both ends to the CCS105 Exploring Coil and the T132EZ or T132B **T** and **R** terminals.

2. Set the spectrum analyzer to **BRDG 600**.

3. Estimate the distance between the CCS105 Exploring Coil and the power line conductors. Average the distance to phase and neutral conductors. This estimate should be made very carefully. The use of a range finder is recommended.

4. Position the CCS105 so that the coil and power line are in the same plane. Then adjust the orientation as required to obtain a maximum reading on the spectrum analyzer.

—CAUTION—

Coupling between a power line and the CCS105 is frequency proportional. For example, one ampere of 900 Hz power line current induces as much voltage in the CCS105 as 15 amperes of 60 Hz current. **For meaningful results, unweighted measurements must**

be made separately for fundamental and each harmonic, using the T132EZ or T132B as a spectrum analyzer.

This general method works on single-phase and two-phase as well as three-phase systems. In general, the spectrum analyzer and CCS105 can be used to determine the amount of ground current in any conductor or group of conductors, including buried telephone cable.

Observe the following precautions when setting up the location of the CCS105:

1. Never locate the CCS105 under a power line span that is carrying secondary distribution leads.
2. Discontinuances in the power line such as bridge taps, corners or dead-ends should be avoided.
3. Metal fences that parallel the power line should be avoided.
4. Joint-use sections with telephone cable should be avoided unless the cable is joint-use throughout the exposure.
5. Buried cable and metallic pipe lines should be avoided.

If these precautions are not taken, large errors in the ground return current measurement result.

The following section describes the use of the CCS105 and T132EZ or T132B in measuring overall ground return current, measuring ground return current at the fundamental frequency (60 Hz) and each harmonic, and making I•T measurements. These applications are preceded by a general description of ground return current.

Ground Return Current

Field tests show that after the continuity of a cable shield is tested and found complete and all grounds are checked and found low resistance, that power influence or voltage-to-ground still exists on the cable conductors. The range is marginal (80-90 dBrnc), or unsatisfactory (over 90 dBrnc). Induced fundamental frequency voltage (60 Hz) to ground on the cable conductors has also been shown to be so high that it seriously affects dial pulsing or ringers connected to ground. When this occurs, other measures should be taken to reduce the power influence. In most cases, reduction of the coupling or distance between the power line and the telephone cable is impractical. Thus, the power line is the remaining variable that can be used to bring the voltage-to-ground or power influence on the cable conductors to within acceptable limits.

The power influence or voltage-to-ground measured on a cable conductor is caused exposure of the cable conductors to the magnetic field. This is produced by the current flowing in the

power line. The magnitude of the power influence is a function of the magnitude of the power line current and its wave shape or harmonic content. The greater the power line current, the higher the power influence.

Power influence is also greater for the higher harmonics of the power line current. This is true for two reasons:

1. Coupling between power line and telephone cable tends to be frequency proportional. Thus the harmonics are more effectively coupled to the telephone circuit.

2. Power influence in telephone circuits is measured with C-message weighting to show the actual impairment and annoyance potential of each frequency component. The power frequency harmonics fall in a much more sensitive portion of the C-message weighting curve than does the fundamental.

If the phase currents in the power line are well balanced, or if the unbalance is carried on a neutral conductor close to the phase conductors, the coupling to the telephone cable tends to cancel out and cause little trouble. The power line current that produces the magnetic field which most seriously affects the telephone cable is the unbalance current. This unbalance current, or Ground Return Current, is forced to return to the power substation through a ground path, far enough away to provide little canceling effect (Figure 1).

Two examples of the effects of ground return current are shown below.

Example 1: Conductor	Current-amperes
Phase A	40
Phase B	40
Phase C	40
Neutral	0
Ground	0

Under the conditions in Example 1, the magnetic field produced that affects the telephone line is very small. Each phase wire is close to another phase wire, the magnetic fields cancel, and no ground return current exists.

Example 2: Conductor	Current-amperes
Phase A	40
Phase B	80
Phase C	40
Neutral	20
Ground	20

Under the conditions in Example 2, the magnetic field produced that affects the telephone cable is much greater than Example 1. Phases A, B, C, and Neutral are in close proximity to each other (two-foot separation), and their magnetic fields approximately cancel. However, *the 20 amperes of ground return current* is returning to the power substation at about 400 feet below the surface and provides very little canceling effect on the magnetic field produced by the associated 20 amperes flowing in Phase B.

Examples 1 and 2 above show that if the power influence or voltage-to-ground on cable conductors is reduced, the ground return current must be reduced to a minimum. There must also be a means of measuring this ground return current. The conventional method of measuring the ground return current is accomplished by the power company. Measurement of each phase wire and neutral is done at a particular location with a clamp-on ammeter. The ground return current is then calculated. This method is accurate but laborious when measurements are required at 10 or 20 locations. The CCS105 is a specially designed inductive coil to be used with the T132EZ or T132B for just such ground return current measurements.

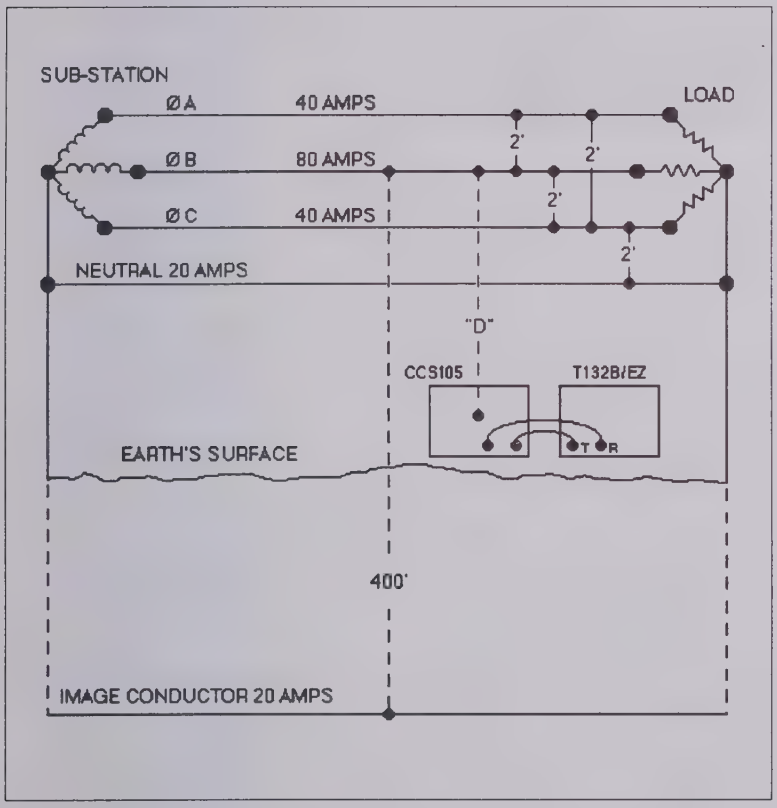
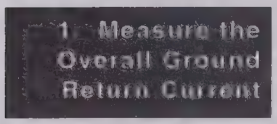


Figure 1. Measurement of Ground Return Current Using the T132EZ or T132B Spectrum Analyzer

Applications



To measure the overall ground return current, including fundamental and all harmonics on an unweighted basis, it is necessary to compensate for the frequency proportional coupling between the power line and the CCS105. This compensation is provided in the spectrum analyzer as an inverse frequency weighting characteristic designated **20/f**.

a. Set up as described in *Using the CCS105* and Figure 1.

b. Set the frequency weighting of the spectrum analyzer to **20/f**.

c. Set the operating mode on the spectrum analyzer to Noise Measurement (T132B only).

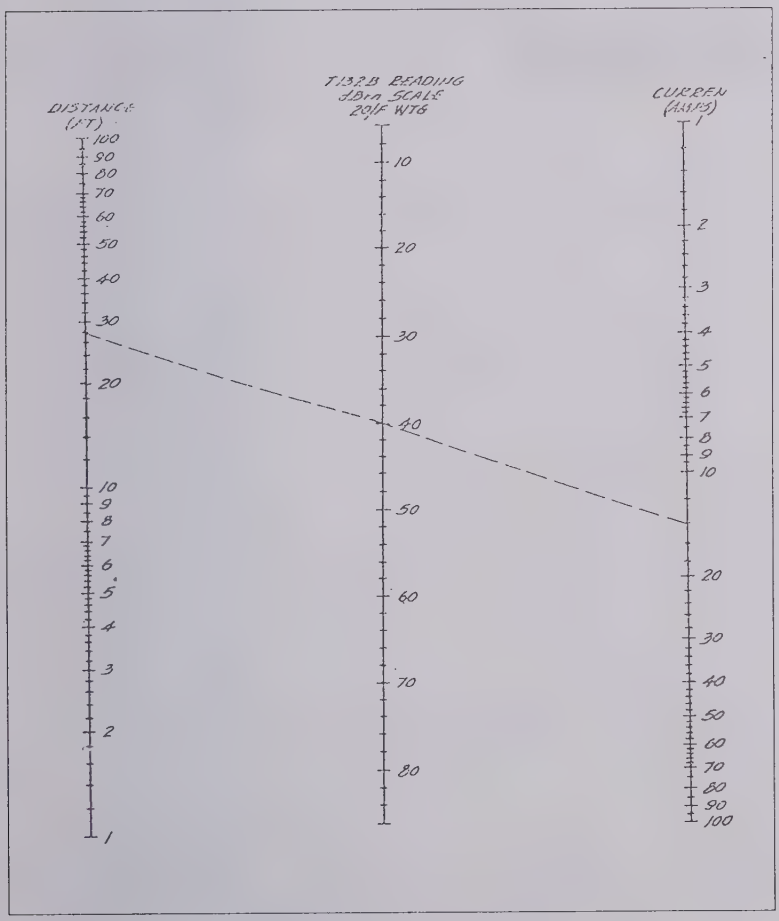
d. Read the noise measurement (dBrnc scale).

e. Estimate the distance in feet between the CCS105 and the power conductors.

f. Apply these two measurements to Nomograph Chart #1 and read the overall ground current in Amperes.

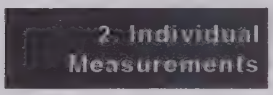
Example:

The distance between the center of the CCS105 and the geometric center of the power phasewire-neutralwire configuration equals 28 ft. The meter reading equals 40 dB. Therefore, the ground return current equals 14 amperes.



Nomograph Chart #1

Determine Overall Ground Return Current

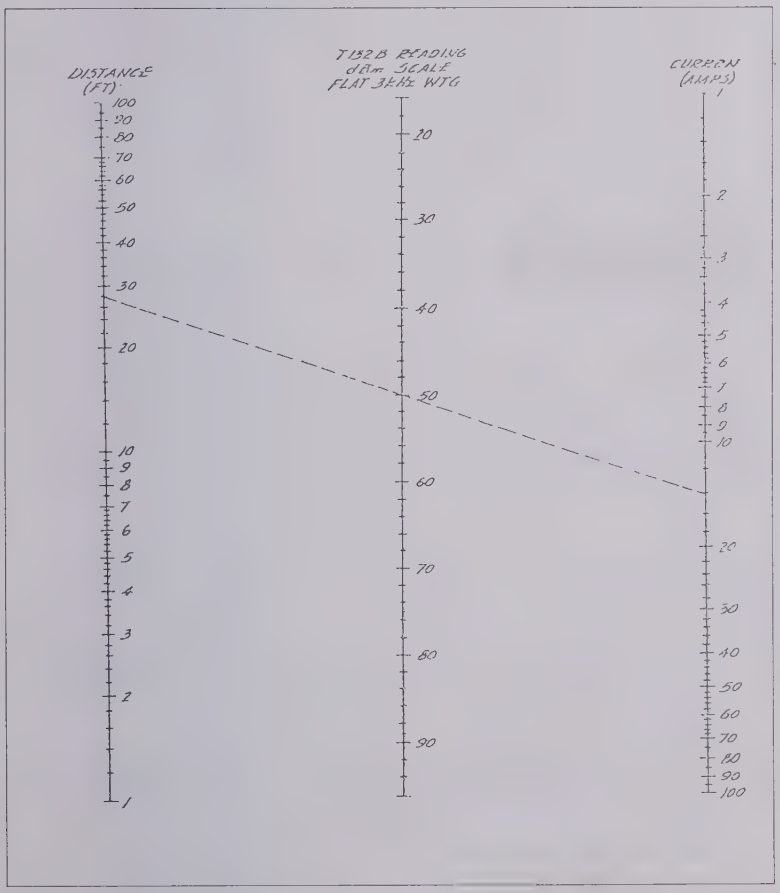


To measure separately the ground return current at the fundamental frequency (60 Hz) and each harmonic, use the following procedure:

a. Set up as described in *Using the CCS105* and Figure 1.
b. Set the spectrum analyzer frequency weighting to FLAT 3 kHz.
c. If using the T132EZ select **04 - Spectrum Data** from the Main menu. On the T132B, set the **OPERATING MODE** switch in **AFC OFF** or **AFC ON**.
d. Tune the spectrum analyzer to the fundamental frequency or harmonic to be read.
e. Read the data (dBrn scale).
f. Estimate the distance in feet between the CCS105 and the power conductors.
g. Apply these two measurements to Nomograph Chart #2 and read the current.
h. For each harmonic, divide the result by the harmonic number (e.g., for 540 Hz divide by 9).

Example:

The distance between the center of the CCS105 and the geometric center of the power phasewire-neutralwire configuration equals 28 ft. The meter reading equals 50 dB. Therefore, the ground return current equals 14 amperes. **Note:** The ground current must be divided by the order of harmonic for other than 60 Hz.



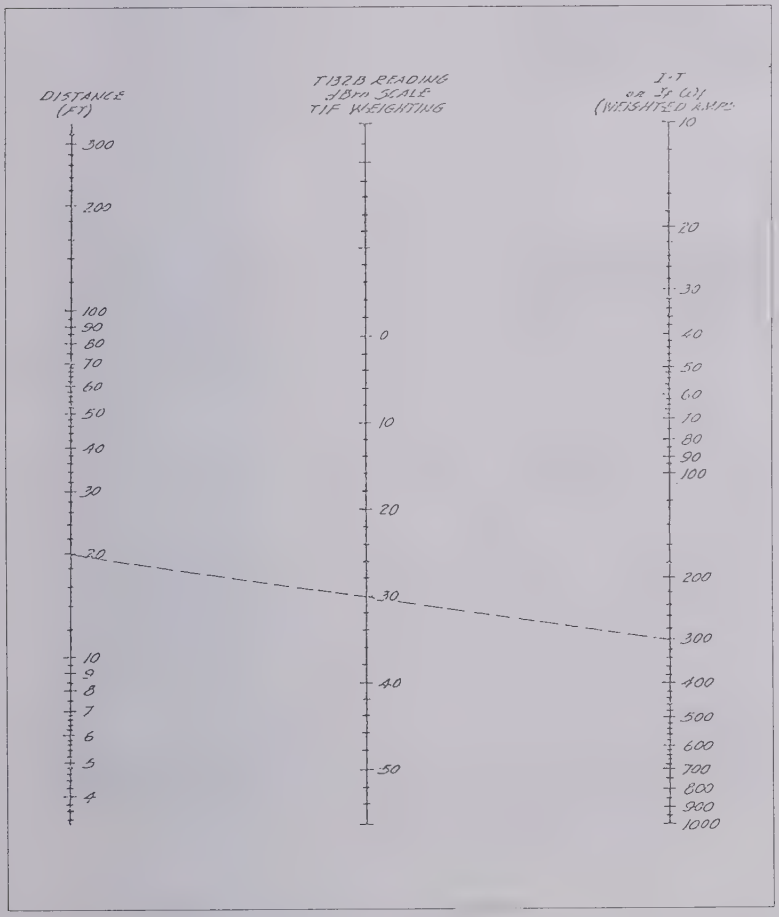
Nomograph Chart #2

Determine Ground Return Current for Fundamental and Each Harmonic Separately

NOTE: The fundamental frequency Ground Return Current, measured in accordance with Application #2, should be close to the overall reading measured in accordance with Application #1. The fundamental and all harmonics measured in accordance with Application #2 and combined on a square-root-of-the-sum-the-squares basis should equal the overall reading measured in accordance with Application #1.

When making I•T measurements, I•T is the current in amperes measured with TIF (Telephone Influence Factor) weighting. TIF weighting is a combination of C-message weighting and a factor equal to five times the frequency; e.g., the TIF weighting factor, W_f ,at 1000 Hz is 5000. The following procedure is applicable to either Overall I•T or to the I•T contribution, I_fW_f, of the fundamental and each harmonic taken separately.

a. Set up as described in *Using the CCS105* and Figure 1.
b. Set the spectrum analyzer frequency weighting to TIF.
c. Set the spectrum analyzer (T132B only) to NMS for overall I•T measurement, or **AFC OFF** or **AFC ON** for I•T contribution I_fW_f measurement.
d. If operating the T132B or T132EZ as a spectrum analyzer, tune to the fundamental frequency or to the harmonic being read. Read the data (dBrn scale).
e. Estimate the distance in feet between the CCS105 and the power conductors.
f. Apply these two measurements to Nomograph Chart #3 and read the overall I•T, or I•T contribution, in TIF-weighted amperes.



Nomograph Chart #3

Determine Weighted Ground Return Current

Applications

For Overall Waveform TIF expressed as a ratio (numerical TIF), divide the Overall I•T as determined in Section 3, by the Overall Current as determined in Section 1.

For TIF Contribution of each harmonic (numerical value), divide I•T contribution ($I_f W_f$) as determined in Section 3, by the Overall Current as determined in Section 1.

Refer to the T132B or T132EZ Operating Instructions for additional information about TIF and I•T.

Data Sheet C of the T132B Operating Instructions may be followed in making Ground Return Current analysis. The proper Height Correction Factors for use with Data Sheet C and the CCS105 are given in Chart #4.

When using Chart #4, enter in Line 5 of the Ground Return Current block of T132B Data Sheet C, Power System Current Waveform Harmonic Analysis.

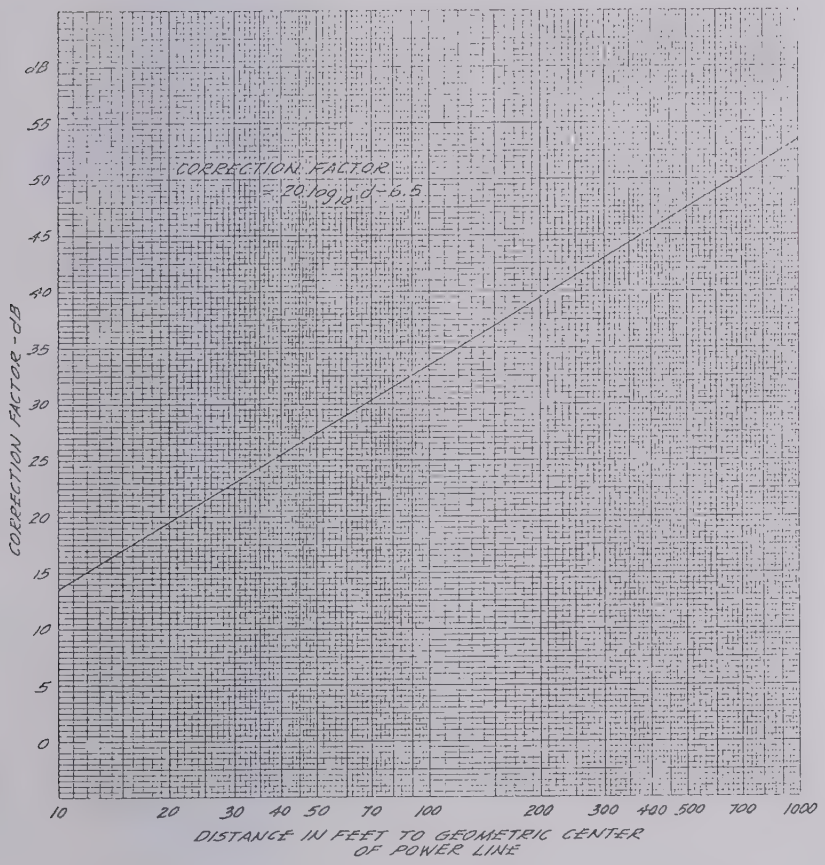


Chart #4

Height Correction Factor for CCS105 and T132EZ or T132B

When an excessive ground return current is determined in a particular exposure, the power company can be contacted. However, before contact is made, determine whether any reasonable resolution can be made by the power company. For example, an unweighted ground return current of 10 amperes is considered to be acceptable. It, therefore, is not practical to expect a power company to reduce the ground return current by an appreciable amount.

However, an unweighted ground return current of 40 amperes results in prompt attention by the power company when notified. The power company should check the ground return current in the exposed sections by means of a clamp-on ammeter to verify the telephone company measurement. Remember that the ground return current varies over a wide range with the time of day. Therefore, a test made by the telephone company should be made at the same time and location as the power company measurement. The primary concern in this test procedure is to determine whether a major imbalance in the power system exists, or if the condition is caused by a change in the telephone system. Therefore, the telephone conditions must be thoroughly checked before contacting the power company.

Theory of Operation

According to the Biot-Savart law, the magnetic field intensity at a distance d meters from a long straight current-carrying wire is given by

$$H = 2I/d \text{ ampere/meter}$$

and the flux density by

$$B = u_o H \text{ weber/meter}^2$$

where u_o is the permeability of free space

$$u_o = 10^{-7} \text{ henry/meter}$$

If we assume that the area of the CCS105 is small enough, in relation to its distance from the power conductors, so that the flux density is constant, the total flux linking the loop is

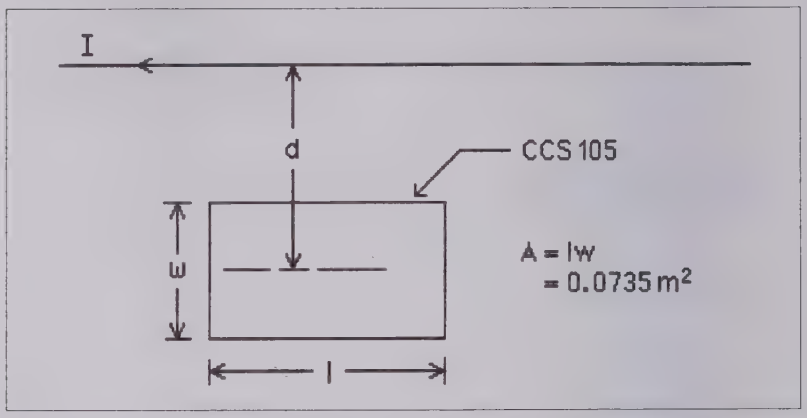
$$\phi = BA = 2 \times 10^{-7} I \, A/_d \text{ webers}$$

The mutual inductance is

$$M = N\phi/I = 2 \times 10^{-7} N \, A/_d \text{ henries.}$$

where dimensions are in meters and N is the number of turns.

Appendix A



For the CCS105, A is approximately 0.0735 m^2, and N = 850. Thus, for d in meters

$$M = 12.5/d\ \mu H$$

or for d in feet

$$M = 41/d\ \mu H$$

The open circuit voltage induced at the terminals is given by

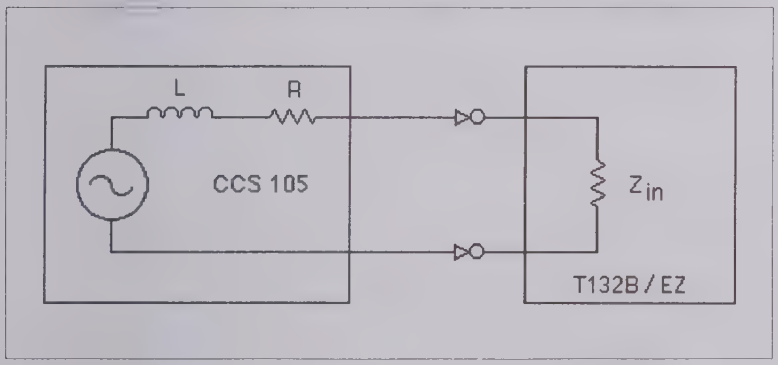
$$V = 2\pi f\ M\ I$$

$$= 258_f\ (I/d)_{\mu V}$$

where f is in Hz, I in amperes, and d in feet.

Measurement

With the spectrum analyzer set in **BRDG**, Z_{in} is high compared to L and R of the CCS105 and can be considered as an open-circuit voltage measuring device. The incoming signal is frequency-weighted by the selected weighting, and then measured. The reading on the dBrn scale is in dB relative to 24.5 µV.



Appendix A

20/f Weighting

The CCS105 output, when 20/f weighting is selected on the spectrum analyzer, may be represented by

$$V = (20/f) \times 258\ f(I/d)\ \mu V$$

$$= 5150\ (I/d)$$

The reading on the dBrn scale is

$$\text{Reading} = 20 \text{ Log } (V/24.5)$$

$$= 20 \text{ Log } (210\ (I/d))$$

$$= 20 \text{ Log } I - 20 \text{ Log } d + 46.5$$

The current, on a dB scale, is given by

$$20 \text{ Log } I = (\text{dBrn reading}) + 20 \text{ Log } d - 46.5$$

which is independent of frequency

$$I = 10\ ((\text{dBrn reading} - 40 + 20 \text{ Log } d - 6.5)/20)$$

Nomograph Chart #1 is based on this expression.

The correction factor which must be entered in block 5 of Data Sheet C (T132B Operating Instructions) is 20 Log d - 6.5. This value is plotted in Chart #4.

Flat Weighting

When the spectrum analyzer weighting is set to FLAT, the voltage from the CCS105 is

$$V = 258\ f\ (I/d)_{\mu V}$$

and the reading is

$$\text{Reading} = 20\ \text{Log}\ (V/24.5)$$

$$= 20\ \text{Log}\ (10.5\ f\ (I/d))$$

At 60 Hz

$$\text{Reading} = 20\ \text{Log}\ (630\ (I/d))$$

$$= 20\ \text{Log}\ I - 20\ \text{Log}\ d + 56$$

The current is given by

$$20\ \text{Log}\ I = \text{dBrn reading} + 20\ \text{Log}\ d - 56$$

$$I = 10\ ((\text{Reading}/20) + \text{Log}\ d - 2.8)$$

At harmonics of 60 Hz, this value must be divided by the order of the harmonic. Nomograph Chart #2 is based on this expression.

Appendix A

TIF Weighting

With the input applied to the **T** and **R** terminals of the spectrum analyzer, the C-Message and TIF positions are identical. An input signal at frequency f is multiplied by the C-message weighting factor C_f, so that

$$V_f = 258\ C_f\ f\ (I/d)_{\mu V}$$

The TIF weighting factor, W_f, is

$$W_f = 5\ f\ C_f$$

so that

$$V_f = 51.6\ ((I_f W_f\ /d)$$

where $I_f\ W_f$ is the TIF-weighted current. The reading is

$$\text{Reading} = 20\ \text{Log}\ ((51.6/24.5)\ \text{x}\ (I_f\ W_f\ /d))$$

$$= 20\ \text{Log}\ (I_f W_f) - 20\ \text{Log}\ d + 6.5$$

From this we see that the I•T contribution for each frequency, $I_f W_f$, is given by adding 30 Log d - 6.5 to the dBrn reading. Since it applies at all frequencies, it is also applicable to overall I•T measured in NMS mode. This expression, converted to numerical values (weighted amperes), is used to develop Nomograph Chart #3.

WARRANTY

All products are warranted against defects in materials and workmanship. This warranty applies for a period of two (2) years from date of delivery, except for Fiber Optic instrumentation and equipment which have a one (1) year warranty on parts and two (2) years on labor. (The only exceptions in the digital testing equipment are the D550 Shark and D550 Hawkeye, which have a warranty of one (1) year from date of delivery.) Wilcom's obligation under this warranty is limited to servicing or adjusting each instrument returned to its factory within the warranty period, and to replace any components found to be defective. If determined that the defective condition is a result of misuse or abnormal operation, repairs will be billed.

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